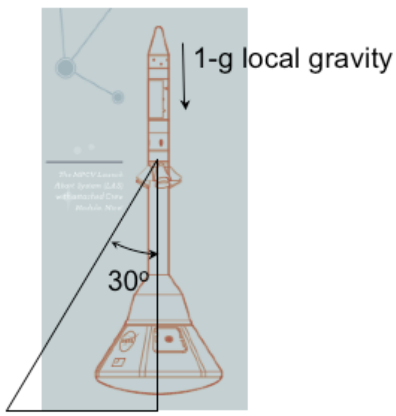
Launch Abort System (LAS) Design Problem

The LAS must protect the crew from deadly pressure waves that would result from the explosion of the launch vehicle. Engineers have determined that the an escape vertical acceleration of 7-g's from a pad explosion would be required to out run the explosion pressure wave. You have been assigned the task of determining the thrust requirements of the LAS abort motor. Through collaboration with other engineers you have found that the initial mass of the Orion capsule and the Launch Abort System is 20,000 kg and that the 4 abort-motor nozzles are canted 30 degrees out from the vehicle. How much thrust must each of the 4 abort-motor nozzles produce to provide the required 7-g escape acceleration?



Help hints

Newton's 2nd law of motion states:
A body of mass (**m**) subject to a net force (**F**) undergoes an acceleration (**a**) that has the same direction as the force and a magnitude that is directly proportional to the force and inversely proportional to the mass, i.e., **F = ma**.

Local gravity at sea level is 1-g or ~9.81 m/s^2

Solution:

Total required acceleration is escape acceleration plus local acceleration.

$a_{total}=a_{escape} + a_{local}$

$a_{total} = 7\ g + 1\ g$

$a_{total} = 8\ g$

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$$a_{total} = 8g \times \frac{9.81 \, m/s^2}{1g}$$

$a_{total} = 78.48\ m/s^2$

Total vertical thrust required is the initial mass times the required total acceleration.

$F_{vertical}=m_{initial} * a_{total}$

$F_{vertical}=20{,}000\ kg * 78.48\ m/s^2$

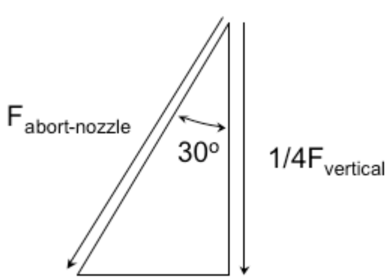
$F_{vertical}=20{,}000\ kg * 78.48\ m/s^2$

$F_{vertical}=1{,}569{,}600\ kg\text{-}m/s^2$

$F_{vertical}=1{,}569{,}600\ N$

$F_{vertical}=1{,}569.6\ kN$

Since each abort nozzle produces ¼th the required vertical force, the required abort nozzle force is ¼th required vertical force divided by the cosine of 30 degrees.



$$F_{abort-nozzle} \times \cos(30^\circ) = \tfrac{1}{4} F_{vertical}$$

$$F_{abort-nozzle} = \frac{\tfrac{1}{4} F_{vertical}}{\cos(30^o)}$$

$F_{vertical}$=¼ * 1,569.6 kN / 0.

$$F_{abort-nozzle} = \frac{\tfrac{1}{4} 1{,}569.6 kN}{\sqrt{3}/2} = \frac{1{,}569.6 kN}{2\sqrt{3}} = 453.1 kN \approx 100{,}000 lb$$